Chemical Bonding and Reactions

PS-4 The student will demonstrate an understanding of chemical reactions and the classifications, structures, and properties of chemical compounds.

PS-4.2 Explain how the process of covalent bonding provides chemical stability through the sharing of electrons.

Taxonomy Level: 2.7-B Understand Conceptual Knowledge

Key Concepts:
Covalent bond
Sharing electrons
Electron pair
Molecule

Previous/Future knowledge: In the 7th grade students were introduced to atoms as summarized in indicator 7-4.1. Students have not been previously introduced to the concepts in this indicator. In Physical Science students will explain the concept of covalent bonding and sharing electrons to become more chemically stable.

It is essential for students to

- Understand that nonmetals have less than the number of electrons that they need in order to have a stable outer-shell arrangement. Nonmetals may gain electrons through ionic bonding or share electrons through covalent bonding to become more stable.
  - It is possible for two nonmetal atoms to share electrons in order to become more stable
    - For example: An atom from group 17 can bond with another group 17 atoms by sharing one electron from each atom. Sharing electrons in this manner results in both atoms attaining eight electrons in their outer energy level and each would have a stable number of electrons equal to the nearest noble gas.
    - The atoms would form one covalent bond consisting of two shared electrons.
    - The *molecule* formed is more stable than the individual atoms.
  - In water, oxygen shares two pairs of electrons, one pair with each of two hydrogen atoms, forming one covalent bond with each. This gives the oxygen atom eight outer energy level electrons and each hydrogen atom, two outer energy level electrons. All of the atoms in the molecule are stable since they each have a number of electrons equal to the nearest noble gas.
  - A hydrogen molecule, H_2, forms a covalent bond by sharing the electron from each hydrogen atom. This gives each hydrogen atom two electrons in the outside energy level which is stable.
- There are many other combinations of nonmetals that achieve electron stability by sharing different numbers of electrons to have a number of electrons like a noble gas (2 or 8 electrons in the outer energy level).
  - Multiple bonds form when more than one pair of electrons is shared. A nitrogen molecule, N_2, has five electrons and needs to gain three electrons to be stable. This sharing is done when three electrons from each nitrogen atom are shared forming a "triple bond" (three covalent bonds). An oxygen molecule, O_2, forms a double bond when two electrons from each atom are shared.
  - A carbon dioxide molecule, CO_2, forms when carbon, which needs four electrons to be stable, shares two electrons from each oxygen atom, which needs two electrons to be stable, forming "double bonds" (two covalent bonds) between each oxygen atom and the carbon atom.

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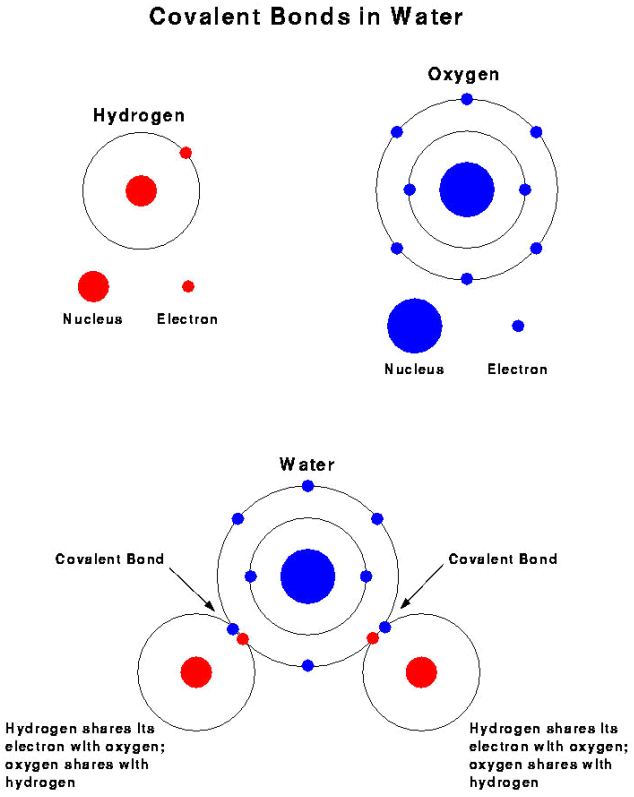
- Show examples of covalent bonding or recognize examples of covalent bonding.
  - Examples may be in the form of "dot" diagrams, pictorial diagrams, or verbal descriptions.
    - Atomic illustrations must indicate which element the illustration represents and the number of electrons in the outer-most energy level of the atom (see PS-2.5).
    - Molecular illustrations must indicate the identity of the elements that compose the molecule and show all atoms sharing electrons in the outer-most energy levels such that each atom in the molecule has a complete outer-most energy level.
    - The shared pairs of electrons in the molecular illustration should be labeled as "covalent bonds"

Example of Electron Dot Diagrams

Example of Pictorial Diagrams



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Example of a Written/Verbal Description

- An atom of hydrogen has one electron in its outer-most energy level. Two electrons are required for hydrogen to have a stable outer-most energy level.
- An atom of chlorine has seven electrons in its outer most-energy level. Eight electrons are required for chlorine to have a stable outer-most energy level.
- A molecule of hydrogen chloride forms when the one electron in the outer-most energy level of a hydrogen atom, and one of the electrons in the outer-most energy level of the chlorine atom are shared.
- The shared electrons occupy both the outer energy level of the chlorine atom and the outer energy level of the hydrogen atom. In the resulting molecule, the hydrogen atom has two electrons in its outer most energy level, (the original hydrogen electron and the electron it is now sharing from the chlorine atom) and the chlorine atom has eight electrons in its outer most energy level, (the original seven chlorine electrons and the electron it is now sharing from the hydrogen atom).
- The sharing of two electrons (one from each atom) is called a covalent bond.

It is not essential for students to

- Understand double or triple covalent bonds with organic compounds;
- Understand molecular shapes;
- Understand resonance;
- Understand hybridization of orbitals.

Assessment Guidelines:

The objective of this indicator is to *explain* how the process of covalent bonding provides chemical stability through the sharing of electrons, therefore, the primary focus of assessment should be to construct a cause and effect model relating covalent bonds to sharing electrons and to achieving stability. Assessments will not only test the student's knowledge that covalent bonds are shared electrons but why they are formed.

In addition to explain, assessments may require that students to

- *Compare* covalently bonded atoms to unbonded atoms;
- *Summarize* covalent bonding and stable configurations;
- *Infer* that particular elements will form covalent bonds;
- *Represent* covalent bonds in dot diagrams, pictorial diagram or word descriptions;
- *Exemplify* covalently bonded compounds;
- *Classify* bonds as covalent or not covalent.